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Evolution of Galaxies and the Star Formation Rate in the Infrared

Grant NAG5-10777

Annual Performance Report No. 1

For the Period 1 May 2001 through 30 April 2002

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May 2002

Prepared for
NASA/Goddard Space Flight Center
Greenbelt, Maryland

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The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

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1 Summary of Research Project

A central goal of extragalactic observational astronomy is to understand how normal galaxies evolve with redshift, and particularly when galaxies formed their stars. While optical and rest-frame UV observations have begun to address these issues, the interpretation of such data is particularly challenging because of the sensitivity to dust obscuration (at optical and UV wavelengths). The absorbed light is re-radiated at IR wavelengths, hence the optimal indicators of the star formation rate (SFR) is at a rest-frame of $\lambda \sim 60\mu\text{m}$.

The SIRTf mission will revolutionize the study of the global evolution of the SFR by providing *mass-selected*, complete samples of galaxies and far-IR estimators of the SFR. This research program is to study the SFR using statistical samples of galaxies in the local universe, at intermediate redshifts, and set the stage for continuing studies up to $z = 5$.

2 Work Performed During the Previous Year

SIRTf Observations. The core of this research program is a large Guaranteed Time Observation (GTO) project with SIRTf to observe nearby and distant galaxies. The following has been accomplished during the past year:

- Re-definition of the three key projects in this research program:
 - A Mid-IR Hubble Atlas and SFR estimators in the local universe,
 - Evolution of the SFR at $0 < z < 1$ using pencil beam redshift surveys, and
 - Galaxy formation and evolution at $1 < z < 5$.
- Constructing and planning these research projects are a large undertaking all by themselves – they total nearly 300 hours of SIRTf observations, i.e., equivalent to more than 12 days of continuous observations! This work involved generating, coordinating, and maintaining literally hundreds of individual observations.
- Submission of complete, revised observing program of Astronomical Observation Requests (AORs) to the SIRTf Science Center.
- Development of concepts for Early Release Observations for the mission, some candidates of which are drawn from the above target lists.
- Simulated the appearance of the Hubble Deep Field when imaged with SIRTf's IRAC instrument.
- Developed predicted redshift distributions for SIRTf observations based on local galaxy properties. These will eventually be compared to the observed distributions.

Other Space Mission Projects. The following were accomplished during the past year:

- Submission of HST, CXO, and XMM proposals for multi-wavelength imaging of SIRTf fields. The HST Treasury Proposal (PI: R. Ellis) was unsuccessful, but will be re-proposed in a scaled-down size.

- Completion of a study of the bulge-to-disk ratios and morphological comparisons for galaxies in a $z = 0.33$ cluster using HST data (Pahre & Siegler 2002).
- On-going progress in studying the radial color gradients in elliptical galaxies at $z = 0.5$ using HST data.

Space Mission Supporting Data. Several additional, complementary datasets are crucial in order to exploit fully the HST, CXO, and SIRTf data for this research program. Since SIRTf has not yet launched, these complementary studies were a considerable effort during the past year. The following have been accomplished during the past year:

- Construction of catalogs of multi-observatory/multi-wavelength datasets, including redshifts and optical photometry.
- Several studies of the global and statistical properties of local galaxies, which make direct predictions as to what will be seen with SIRTf.
 - Measurement of the rest-frame K -band luminosity function of nearby galaxies (Kochanek et al. 2001), which produces the baseline comparison sample that will be observed with SIRTf filters (3.6, 4.5, 5.8, 8.0 μm) at $z = (0.6, 1.1, 1.6, 2.6)$.
 - Measurement of the internal velocity and mass functions of galaxies in the local universe (Pahre et al. 2002a,b), which will compare directly to the velocity function at $z = 1$ from the combined SIRTf and DEEP-2 dataset.
- Unsuccessful proposal for VLA observing of SIRTf fields – will be re-proposed.
- Successful imaging of one SIRTf field of $10' \times 2^\circ$ (the “Extended Groth Strip”) in the K -band with the MMT. This near-infrared photometry is key to obtaining photometric redshifts with SIRTf at $0 < z < 1$ (Simpson & Eisenhardt 2001). These data are nearly fully reduced and a publication on their properties is expected.

3 Work for the Coming Year

- SIRTf launch 2003 January 9: This research program should become deluged with data during the next year. Many of the targets are being scheduled with SIRTf as high priority – and hence will be observed during the first six months or first year of normal SIRTf operations.

This work will most likely generate a number of quick papers approximately one year from now – IR galaxy counts, extremely red objects (only detected with SIRTf), etc.

- Redshifted $H\alpha$ spectroscopy of galaxies at $z = 1$: This will be done with the MMT during the next year for a K -band selected sample, that will immediately be supplemented by a small number of SIRTf-selected extremely red objects. This will be a measure of the $H\alpha$ estimated SFR at $z = 1$, and will be compared directly with the SIRTf far-infrared derived SFR at the same redshifts, and also rest-frame UV measurements (already published). These comparisons will be crucial for understanding biases in SFR indicators.
- Re-propose for complementary datasets (HST and VLA), and initiate an HST/ACS UV imaging survey of nearby 2MASS-selected galaxies.
- Work on various kinds of photometric redshift predictors using combined HST and SIRTf datasets. This will be important for creating large statistical samples of galaxies at high redshift.

- Complete work and publish on the radial color gradients of elliptical galaxies at $z = 0.5$ (HST data).
- Complete work and publish results from the near-IR imaging of the EGS region.
- Supervised research: It now appears probable that a Harvard graduate student will join the studies of local galaxies that form part of this research program.

4 Publications During the Past Year (Submitted, Revised, and/or Published)

- The Velocity Function of Galaxies. Pahre, M. A., Kochanek, C. S., & Falco, E. E. 2002, ApJ, submitted.
- Bulge-Disk Decomposition and the Morphological Classifications of Galaxies in Cluster MS1358+62 at $z = 0.33$. Pahre, M. A., & Siegler, N. 2002, ApJ, submitted.
- The K-Band Galaxy Luminosity Function. Kochanek, C. S., Pahre, M. A., Falco, E. E., Huchra, J. P., Mader, J., Jarrett, T. H., Chester, T., Cutrie, R., Schneider, S. E., & Skrutskie, M. 2001, ApJ, 560, 566.
- Evidence for Inconsistencies in Galaxy Luminosity Functions Defined by Spectral Type. Kochanek, C. S., Pahre, M. A., & Falco, E. E. 2000, ApJ, submitted; 2002, revised.
- The Redshift of the Optical Transient Associated with GRB 010222. Jha, S., Pahre, M. A., Garavich, P. M., Calkins, M. L., Kilgard, R. E., Matheson, T., McDowell, J. C., Roll, J. B., & Stanek, K. Z. 2001, ApJL, 554, 155.
- The 2MASS Luminosity, Velocity, and Mass Functions of Galaxies. Pahre, M. A., Kochanek, C. S., & Falco, E. E. 2002, in proceedings of The Mass of Galaxies at Low and High Redshifts, eds. A. Renzini & R. Bender, in press.

